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APPARENT ABUNDANCE INDICES FOR SIX PELAGIC SPECIES: 1962-1990, AS DETERMINED BY AN AERIAL MONITORING PROGRAM

By

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BACKGROUND

The National Marine Fisheries Service's (NMFS) aerial monitoring program for pelagic species off California and northwestern Baja California, Mexico began in the fall of 1962. The first full year of observational data from aerial fish spotters under contract was in 1963. Details concerning the monitoring program, its procedures for recording data and reviews of findings may be obtained from publications by Squire (1972, 1983) and Caruso (1979).

Aerial fish spotter pilots searching for fish for the commercial purse seine fleet have maintained flight logs for NMFS. At the completion of each flight, the pilot notes on the flight log chart the flight track, time of flight (day or night) an estimate of the tonnage observed for each species, and the location where observed. Species more commonly observed are the northern anchovy, (*Engraulis mordax*), Pacific sardine (*Sardinops sagax*), Pacific bonito (*Sarda chiliensis*), Pacific mackerel (*Scomber japonicus*), jack mackerel (*Trachurus symmetricus*) and bluefin tuna (*Thunnus thynnus orientalis*).

Analysis of the first 10 years of aerial data indicated that certain species were observed more frequently and in greater numbers during the day, and some species were more readily observed at night (Squire 1972). Species that were observed more frequently and in greater quantity at night were the northern anchovy, Pacific mackerel, jack mackerel, and Pacific sardine. Pacific bonito and bluefin tuna were more commonly observed during the day.

Flight log data are coded into the Southwest Fisheries Science Center's computer and annual computations are made giving observation effort by zones, tonnage of the various species observed in these zones by time interval (day, night and combined period). An index of apparent abundance is calculated for each species. It is based on the number of 10" longitude by 10" latitude areas searched, and these areas are known as "block areas". A flight within a block area is described as a block area flight (BAF). A chart of block areas and zones is given on Figure 1. The apparent abundance index value is given in terms of tons observed per block area flight (T/BAF).

In recent years, the analysis procedure has been modified to determine an apparent abundance index for the core area of distribution for each of the six species. The core area index is a weighted mean index (Cochren, 1966) and is calculated for each species according to optimum observation time, day or night. This index value is also expressed as T/BAF.

This paper presents a condensed review of the distribution of aerial fish spotting effort by zone (day and night) and the apparent abundance indices for six species, all zones combined, day and night. Also, the core area abundance index (day or night) is given for each species, 1962-1990. A detailed description of the methods used in calculating the core area and total index values is given.

Apparent abundance data

Calculations of abundance indices given in Tables 1-8 include effort and sightings of all pilots participating in the program, with the exception of one pilot whose estimates were near double the estimates of other spotter pilots working in the same area (identified as #26 in the computer file). The estimate of tonnage observed by all pilots are combined and divided by the total search effort. Although it is presumed that pilots do not estimate tonnage equally, no proof exists of differences. Pilots are consistently obtaining "ground truth" of their sightings from catches made by the purse seiner.

Annual index values were determined rather than seasonal values since the majority of search effort and sightings is during the summer and fall, a period of greater abundance of fish resources off northwest Mexico and California. Over 48% of the aerial spotting effort is recorded during the months of July, August and September.

Table 1 gives the distribution of search effort in terms of BAF conducted by zone, day and night. For geographical location of zones, see Figure 1. In the 28 years of operation, aerial fish spotter pilots have recorded searching all or portions of 375,574 block areas (BAF) with 67% of the search effort conducted during the day and 33% during the night. The annual amount of search effort has varied with the average being 13,382 BAF per year.

Table 2 gives the distribution of search effort in terms of BAF for the various zones, and their ranking, according to number of BAF.

Tables 3 - 8 give the annual apparent abundance indices (T/BAF) for each species, for the total area, day plus night, and for the core area of distribution. The best search time selected (day or night) was based on whether the species occurrence in the upper layers of the ocean is primarily during the day or night.

Calculation of total area and core area apparent abundance indices

The statistical procedures for calculating the total area and core area apparent abundance indices are relatively simple and are given for each index.

The total area index uses all effort and tonnage data for the coastal area from near Monterey Bay, California to Cedro Island, Mexico. The total area index (day or night, or combined) is computed using the formula;

Index: Tons per block area flight - T/BAF

Where:

T = total tonnage observed
BAF = number of block area flights

The index value represents the amount of fish observed divided by the amount of search effort. For a description of how the BAF is determined, see Squire (1972).

The core area geographical boundaries for each species are based on an analysis of the distribution of sightings, 1962-1978. Although the geographical boundary may include portions of several zones, the primary concentration is located within the core area boundary, not in the portion of the zone outside the core area.

The core area apparent abundance index for each species is calculated using data from the time period (day or night) best representing the species. The method used calculates a weighted mean of T/BAF from a portion of each zone comprising the core area (see Figure 2). For each zone, the weight was the ratio of the total number of block areas having high species density in the zone, to the total number of block areas with high density comprising the entire core area.

$$\Sigma \, Wi \, (T/BAF)i;$$

Where:

Wi = weight for zone i.
(T/BAF)i = T/BAF for zone i.

Each weight (Wi) is the ratio of the total number of block areas comprising the entire core area.

Figure 2 is an example of a core area of abundance (no specific species). In the core area outlined, the number of equivalent block areas (total area) per zone is;

Zone	=	Block areas
G	=	5
H	=	6
I	=	2
J	=	1
		14 total block areas in core area.

To determine the weighting factor for the T/BAF for each zone, the number of block areas in each zone is divided by the total number of block areas in the core area. The total number of block areas comprising the core area for each species is given in Table 9.

Zone	Block Areas		Weighting Factor
G	= 5/14	=	0.35
H	= 6/14	=	0.42

I = 2/14 = 0.14
J = 1/14 = 0.07

To determine the index value (T/BAF) for the core area, the T/BAF calculated for each zone that is part of the core area is multiplied by the weighting factor, then totalled:

T/BAF x Weighting Factor = Index value (sample area)

G = 8.57 x 0.35 = 2.99
H = 22.59 x 0.42 = 9.48
I = 7.30 x 0.14 = 1.02
J = 5.60 x 0.07 = 0.39
T/BAF for the core area = 13.88

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Caruso, Joseph P. 1979. Aerial marine monitoring system. NOAA/NMFS Southwest Fisheries Center, La Jolla, CA. April 1979, 99p.

Squire, James L. 1972. Apparent abundance of some pelagic marine fishes off southern and central California coast as surveyed by an airborne monitoring program. Fish.Bull., U.S. 70:1005-1019.

Squire, James L. 1983. Abundance of pelagic resources off California, 1963-78, as measured by an airborne fish monitoring program. NOAA tech.Rep. NMFS-SSRF-762, 75 p.

Table 1. Search effort in terms of block areas searched (block area flights - BAF), day and night, 1962-1990.

	BLOCK AREA FLIGHTS		
YEAR	DAY	NIGHT	TOTAL
1962	362	512	874
1963	3,541	3,279	6,820
1965	5,245	3,415	8,660
1966	7,708	3,781	11,489
1967	7,632	3,495	11,127
1968	7,823	3,835	11,658
1969	9,745	5,896	15,641
1970*	4,646	1,853	6,499
1971	12,308	5,181	17,489
1972	7,402	4,448	11,850
1973	12,450	5,031	17,481
1974	8,356	3,887	12,243
1975	7,923	3,398	11,321
1976	14,782	3,781	18,563
1977	7,795	7,788	15,583
1978	6,517	4,415	10,932
1979	10,727	4,767	15,494
1980	3,624	3,403	7,027
1981	9,237	3,781	13,018
1982	9,597	4,571	15,351
1983	13,904	4,571	18,475
1984	9,144	1,063	10,207
1985	15,243	4,031	19,274
1986	12,300	5,684	17,984
1987	8,474	6,348	14,822
1988	7,185	3,335	10,520
1989	8,744	4,116	12,860
1990	16,101	8,504	24,605
63-90	253,239	123,207	375,574
	= 67% day	= 33% night	Total

Average = 13,832 BAF/year, 1963-1990

* Flight log data collected only during the second half of 1970.

Table 2. Distribution of effort in terms of "block area flights" (BAF) by zone and ranking of zones, based on number of BAF during the period 1962-1990.

Zone	BAF	Area	Sighting rank
A	4,978	Monterey	13
B	7,707	Avila	12
C	74,714	Santa Barbara Channel	1
D	58,581	Santa Barbara Islands	3
E	11,149	San Nicolas/Santa Barbara Islands	10
F	8,480	Cortez Bank	11
G	62,273	Los Angeles	2
H	29,645	Catalina Island	5
I	28,677	San Clemente Island	6
J	41,708	San Diego/Dana Point	4
K	11,335	Offshore Ensenada	9*
L	19,619	Ensenada	7*
M	671	Offshore Cabo Colnett	16*
N	12,333	Cabo Colnett	8*
O	48	Offshore Punta Baja	18*
P	4,016	Punta Baja	14*
R	1,235	S. Punta Canoas	15*
T	104	Cedros Island	17*

* These zones flown almost exclusively for bluefin tuna (day operations).

Table 3. Northern anchovy - Core area index (Zones G, D, C & H), night weighted mean. Total area index (day plus night), both indices in T/BAF.

Year	Core Area	Total Area	Year	Core Area	Total Area
1962	0.09	0.66	1977	858.73	713.80
1963	250.98	141.38	1978	263.89	340.19
1964	160.55	80.66	1979	624.80	382.83
1965	253.85	153.45	1980	578.68	322.01
1966	116.92	83.26	1981	236.71	89.87
1967	225.70	163.63	1982	67.86	42.78
1968	173.41	72.20	1983	7.72	4.17
1969	309.84	195.82	1984	6.76	4.54
1970	629.03	608.43	1985	47.88	27.24
1971	362.59	195.63	1986	13.39	7.55
1972	54.55	81.05	1987	33.28	20.67
1973	1143.55	745.98	1988	69.20	42.90
1974	494.29	354.25	1989	7.24	16.05
1975	1010.70	819.93	1990	31.45	11.96
1976	456.10	293.77			

Table 4. Pacific sardine - Core area index (Zones C, D, G & H), night, weighted mean. Total area index (day plus night), both indices in T/BAF. - indicates an abundance level of <0.01 T/BAF.

Year	Core Area	Total Area	Year	Core Area	Total Area
1962	-	-	1977	-	-
1963	1.38	0.77	1978	-	-
1964	1.31	0.90	1979	-	-
1965	0.02	0.04	1980	-	-
1966	0.03	0.02	1981	-	0.01
1967	-	-	1982	0.24	0.12
1968	0.01	-	1983	0.33	0.15
1969	-	-	1984	2.77	1.88
1970	-	-	1985	97.36	34.37
1971	-	-	1986	32.35	19.87
1972	-	-	1987	20.12	11.76
1973	-	-	1988	145.75	77.11
1974	-	-	1989	34.84	6.23
1975	-	-	1990	39.03	11.83
1976	-	-			

Table 5. Pacific mackerel - Core area index (Zones C, D, G, H & I), night, weighted mean. Total area index (day plus night), both indices in T/BAF. - indicates an abundance level of <0.01 T/BAF.

Year	Core Area	Total Area	Year	Core Area	Total Area
1962	4.04	2.74	1977	104.80	72.30
1963	3.36	6.62	1978	198.72	142.26
1964	1.63	1.06	1979	85.27	63.75
1965	0.80	0.41	1980	58.78	39.10
1966	0.51	0.23	1981	41.74	31.59
1967	0.01	-	1982	29.24	26.71
1968	0.01	-	1983	19.00	8.89
1969	0.07	0.03	1984	59.91	72.44
1970	2.95	0.83	1985	148.18	88.73
1971	0.33	0.13	1986	85.48	41.77
1972	0.10	0.03	1987	36.06	17.38
1973	0.43	0.18	1988	43.55	21.66
1974	-	-	1989	7.83	3.53
1975	-	0.02	1990	3.19	3.18
1976	0.05	0.47			

Table 6. Pacific bonito - Core area index (Zones C, D, G & J), day weighted mean. Total area index (day plus night), both indices in T/BAF. - indicates an abundance level of 0.01 T/BAF.

Year	Core Area	Total Area	Year	Core Area	Total Area
1962	2.20	1.18	1977	0.23	0.14
1963	2.29	6.28	1978	0.96	4.35
1964	3.39	2.32	1979	0.38	0.31
1965	5.88	3.47	1980	0.38	0.33
1966	14.84	10.16	1981	1.78	1.73
1967	7.20	5.34	1982	0.56	0.38
1968	3.35	3.06	1983	1.31	0.96
1969	1.58	1.50	1984	9.93	8.17
1970	-	0.87	1985	3.98	3.22
1971	3.47	2.93	1986	0.30	0.22
1972	2.83	2.28	1987	1.05	0.70
1973	3.34	2.98	1988	2.42	1.55
1974	1.76	1.40	1989	1.23	0.98
1975	0.74	0.48	1990	1.15	0.76
1976	0.59	0.43			

Table 7. Jack mackerel - Core area (Zones D, F, G, H & I), night index weighted mean and for total area (day plus night) in T/BAF.

Year	Core Area	Total Area	Year	Core Area	Total Area
1962	5.28	5.04	1977	91.41	60.40
1963	23.10	13.73	1978	74.90	82.54
1964	14.69	11.56	1979	20.13	19.13
1965	14.58	9.97	1980	12.25	9.23
1966	4.49	2.70	1981	7.77	4.42
1967	15.26	6.61	1982	10.14	6.15
1968	24.21	11.41	1983	2.20	1.56
1969	5.68	3.55	1984	7.47	1.82
1970	2.91	1.87	1985	6.23	1.61
1971	12.55	5.91	1986	2.63	1.44
1972	11.65	6.27	1987	1.69	1.01
1973	0.39	0.21	1988	1.03	0.47
1974	3.41	1.88	1989	2/86	1.37
1975	13.17	5.69	1990	0.81	0.23
1976	11.59	3.89			

Table 8. Bluefin tuna - Core area index (Zones I, K, L, N & P), day weighted mean. Total area (day plus night), both indices in T/BAF. - indicates an abundance level of <0.01 T/BAF.

Year	Core Area	Total Area	Year	Core Area	Total Area
1962	6.57	4.40	1977	8.71	7.12
1963	6.97	6.81	1978	34.52	30.07
1964	6.97	6.81	1979	12.87	12.32
1965	1.28	0.90	1980	0.89	0.69
1966	13.03	9.46	1981	0.95	0.80
1967	4.51	3.42	1982	1.37	1.27
1968	9.45	6.03	1983	0.05	0.20
1969	0.59	0.39	1984	0.62	0.66
1970	-	0.02	1985	2.32	2.57
1971	0.87	0.42	1986	1.98	3.03
1972	6.94	2.75	1987	0.77	0.55
1973	17.38	16.45	1988	1.23	0.56
1974	18.32	17.28	1989	1.02	0.48
1975	2.60	2.54	1990	0.73	0.35
1976	13.73	13.20			

Table 9. Number of block areas comprising the core areas for the northern anchovy, Pacific sardine, Pacific mackerel, Pacific bonito, jack mackerel and bluefin tuna.

Species	Zone	No. Blocks
Northern anchovy	G	10
	D	11
	C	10
	H	6
		37
Pacific sardine	C	6
	D	5
	G	5
	H	4
		20
Pacific mackerel	G	6
	H	3
	I	3
	D	5
	C	4
		21
Pacific bonito	C	6
	D	8
	G	8
	J	7
		29
Jack mackerel	D	8
	G	7
	H	3
	I	3
	F	4
		25
Bluefin tuna	I	20
	L	20
	K	15
	N	18
	P	8
		81

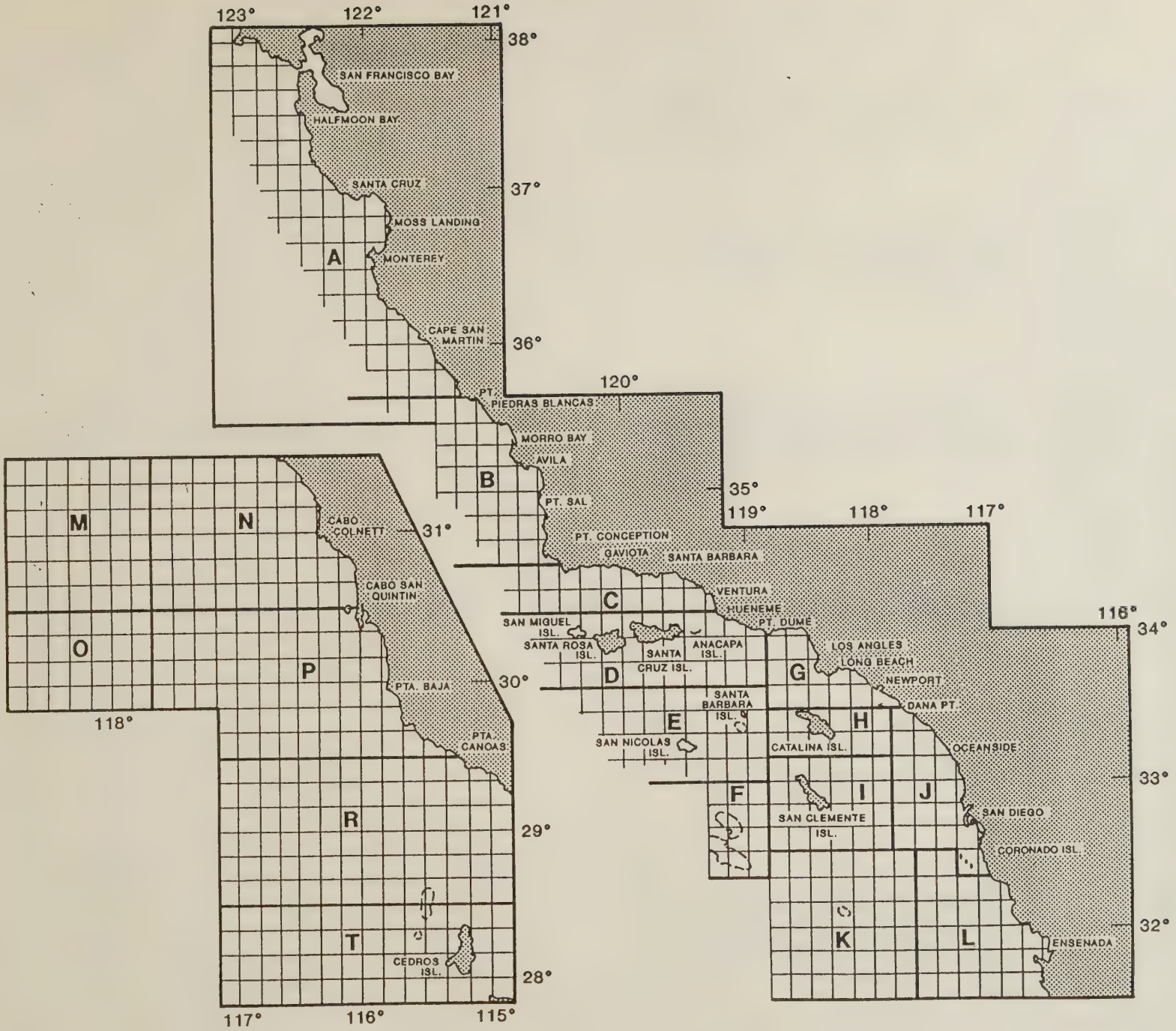

Figure 1. Block areas and zones A-P, R and T, San Francisco, CA to Cedros Island, Mexico.

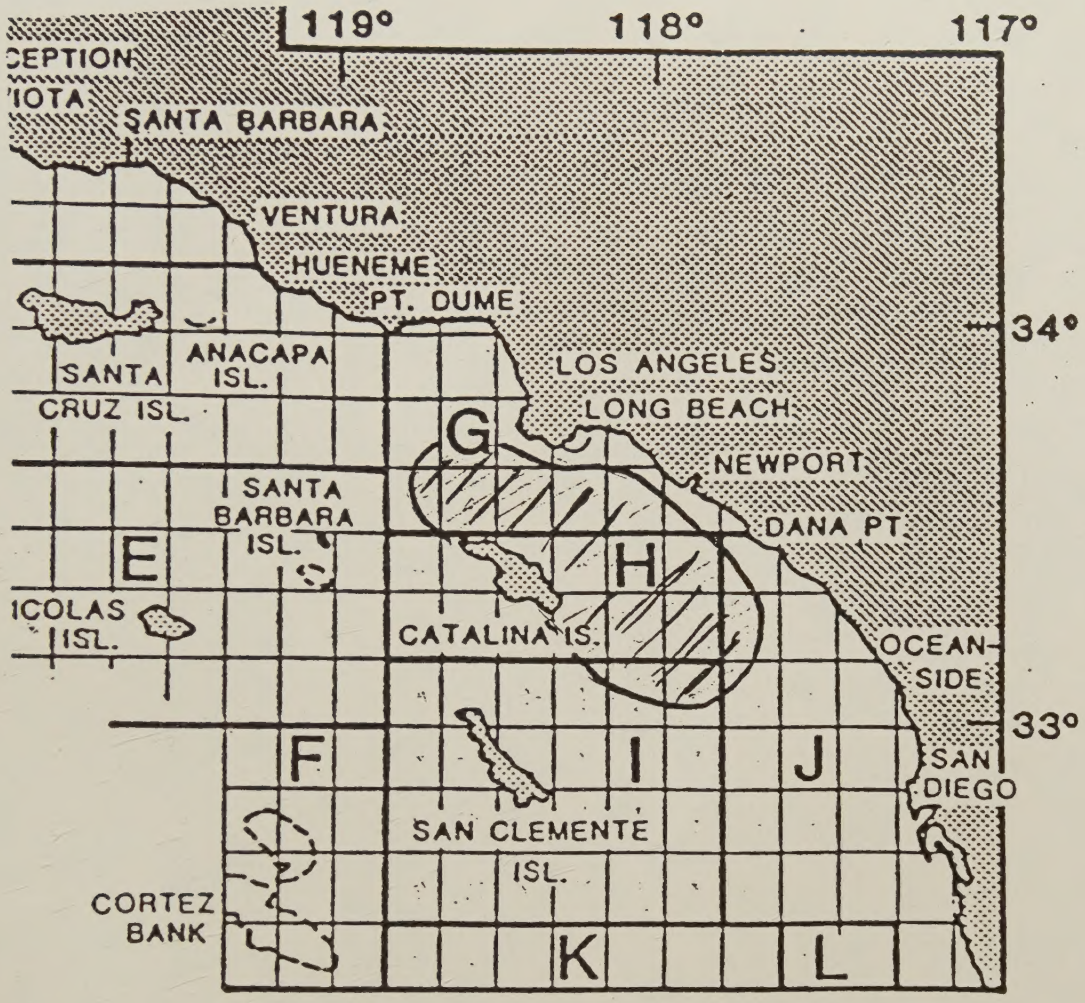

Figure 2. Example of a core area of abundance (no specific species).